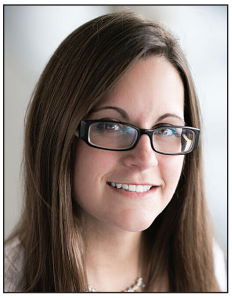
Sugar Reduction and Use of Bulking Agents in Confections:

An Overview of Functional Properties

Consumer demands and labeling regulations for reduced sugar are driving confectioners to find functional ingredients that meet these new expectations.

Melissa Riddell
Batory Foods



Melissa Riddell is the technical service manager at Batory Foods. She has been at the company since 2014. Her previous experience includes positions at Tate & Lyle, King & Prince Seafood and ACH Foods.

Consumer awareness of ingredients and their impact on health continues to grow as ingredient information becomes more readily available across multiple platforms. This has helped create a demand for more natural, purer products and labeling indicating fewer artificial ingredients. Shoppers are seeking products with minimal processing and avoiding ingredients perceived as negative, with sugar reduction being the primary goal in new formulation development (Figure 1).

The FDA now recognizes this consumer-driven goal with new regulatory requirements on labeling. In a press release in September 2018 by FDA Commissioner Scott Gottlieb, MD, the FDA communicated its goal to increase consumer awareness of the quantity of added sugars in food products. With updated label requirements, the FDA hopes consumers can better understand how foods with added sugars can fit into a healthy dietary pattern.

Consumer demands for reduced sugar consumption and the new labeling regula-

Product Claims Shoppers Seek When Purchasing a Food Product

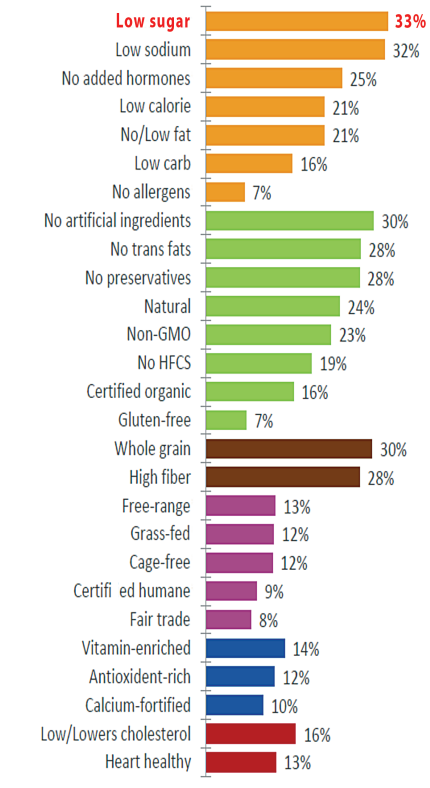


Figure 1 *U.S. Grocery Shopper Trends 2017*

tions have the most impact on the confectionery industry as the manufacturers of these products and brands are driven to find functional ingredients to achieve these higher standards.

KEY CONSIDERATIONS WHEN REDUCING ADDED SUGARS

When formulating an application with a nutrition strategy in mind, there are many factors that must be considered, including consumer interest and acceptability, eating quality, shelf life and regulations. When focusing specifically on decreasing sugar in confection applications, the formulation challenges increase in order to address the need for sweetness while also satisfying functional goals of physical property characteristics such as crystallization and texture, mouthfeel (viscosity), and hygroscopicity (shelf stability) (Figure 2).

More specifically, these functional goals involve controlling specific variables to achieve an appropriate balance of increased product purity while also meeting consumer expectations of consumption experience with the product:

1. Equivalent sweetness
2. Crystallization and texture
3. Flavor, sensation and color
4. Shelf stability

We look at specific ways to achieve this balance and satisfy these goals in the following overview of sugar substitute properties.

Strategies for decreasing added sugars include the use of high-potency sweeteners, polyols, soluble fibers and nutritive sweetener synergies. When choosing a strategy, formulators must also consider consumers' concerns, including tolerance and price demands.

Sugar substitutes are divided into general categories (Figure 3) that include bulk sweeteners, bulking agents and high potency sweeteners. Each sugar substitute affects the formula in a different way, however, the right combination can result in a pleasing flavor and the desired performance.

Sweetness

With sweetness being the first functional goal and attribute when reducing sugars in confections, high potency, non-nutritive and nutritive sweeteners often offer the ideal solution. These options also allow a developer to take advantage of sweetener synergies (Figure 4) for improved flavor, intensity and aftertaste or linger.

The sweetness perception curve shown in Figure 4 indicates the temporal profile of a sweetener (at the same relative intensity) showing the onset and linger potential of that sweetener. Based on this data, combining multiple sweeteners allows a formulator to control negative attributes by balancing onset with linger. This is demonstrated in the common use of erythritol combined with stevia extract. Since erythritol has a rapid onset of sweetness,

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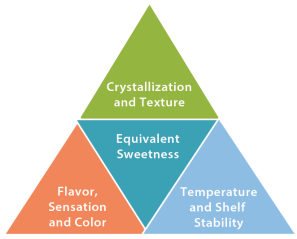
Sweetener Functional Goals



1. Equivalent Sweetness
   - Sweetness Perception
   - Sweetness Synergies
   - Masking Agents
2. Crystallization and Texture
3. Flavor, Sensation and Color
   - Cooling Effect
   - Browning
4. Temperature and Shelf Stability

Figure 2

Sugar Substitute Categories

1. Polyols (Sugar Alcohols)
   Sorbitol, maltitol, erythritol, isomalt, glycerin, etc.
2. Other Functional Bulking Agents
   Soluble corn fiber, wheat dextrin, inulin, maltodextrins, etc.
3. Nutritive Sweeteners
   Fructose, allulose, trehalose, molasses, honey, agave syrup, etc.
4. High Intensity Sweeteners
   Natural: stevia leaf extract, monkfruit extract, Reb M (steviol glycoside)
   Non-Natural: Sucralose, Acesulfame K, aspartame, etc.
5. Fruit Powders and Concentrates

Figure 3

At some point, adding more high-potency sweetener will not make an application sweeter because the perception and intensity will plateau.

it counter-balances the long linger associated with stevia extracts while still maintaining a clean label. However, it is important to note that high-potency sweeteners have greater intensities at low sweetness levels than at high sweetness levels. At some point, adding more high-potency sweetener will not make an application sweeter because the perception and intensity will plateau.

Taking advantage of sweetener synergies is also a way to reduce total sugars in any application. Some sweeteners—when combined—exhibit greater than expected sweetness. Sweetness synergy becomes more pronounced as the level of sweeteners increases. These synergies cannot be predicted from the properties of the two sweeteners alone and must be determined experimentally.

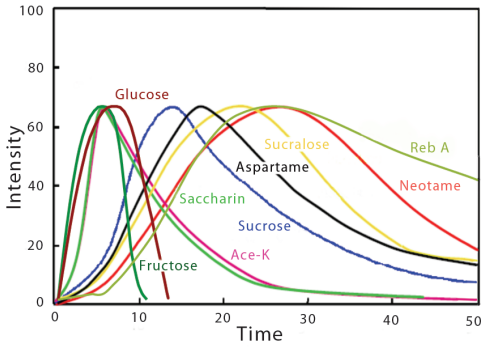
Sugar reduction can even be achieved using only nutritive sweeteners through sweetness synergy. For example, combining equal parts of sucrose and fructose will result in an overall 25 percent increase in intensity perception. This increased perception can allow a formulator to use up to 25 percent less total sugars while maintaining desired sweetness. Sucralose is the most commonly used high-potency sweetener with multiple synergies to magnify sweetness; it can be used with other artificial high-potency sweeteners and also with nutritive sweeteners and polyols (see Figure 4).

Solubility and Crystallization

The most common bulk sweeteners used in confections today are sugar alcohols or polyols. One of the most frequent problems with utilizing polyols is the ingredient's effect on crystallization. All sweeteners are readily soluble in water, but increasing solubility lessens crystallization (Figure 5). Typically, the solubility of polyols increases substantially through increasing temperature. Heat and super-saturation, followed by carefully controlled cooling, may inhibit crystal formation similar to sugars. However, if temperature is not carefully controlled, super-saturated solutions, which are commonly used in confectionery, are unstable and can crystallize too rapidly.

In meeting the second goal of controlling crystallization and texture, when controlled crystallization is desired, polyols with lower solubility, such as mannitol,

Functional Goal 1: Controlling Sweetness – Utilizing Sweetener Synergies to Modify Sweetness Perception



Sweetness Perception

Combinations of early-onset sweeteners, such as ace-K, fructose or erythritol, with late-onset sweeteners that linger, such as sucralose or stevia extracts, can result in an overall sweetness perception more similar to sucrose, the industry gold standard.

SYNERGY PRESENT
SUCROSE : FRUCTOSE
ASPARTAME : ACESULFAME K
ASPARTAME : SACCHARIN
ASPARTAME : CYCLAMATE
CYCLAMATE : SACCHARIN
CYCLAMATE : ACESULFAME K
MONKFRUIT EXTRACT : SUCROSE
MONKFRUIT EXTRACT : FRUCTOSE
SUCRALOSE : ACESULFAME K
SUCRALOSE : ASPARTAME (SLIGHT)
SUCRALOSE : NUTRITIVE SWEETENER(S)
SUCRALOSE : POLYOLS

Blend	Synergy
Sucrose / sucralose	7%
Invert Syrup / sucralose	22%
HFCS 55 / sucralose	24%
Sucralose / xylitol	10%
Sucralose /mannitol	10%
Sucralose / sorbitol	13%
Sucralose / isomalt	16%
Sucralose / maltitol	3%
Sucralose / lactitol	14%

Made to 5% SEV Level

Figure 4

Adapted from Birch (1996); Spillane (2010) and Tate & Lyle (2010)

isomalt and erythritol, provide varying levels of crystal formation and size, which impart desired ranges of texture, from granular to crystalline. With higher solubility, polyols like sorbitol, maltitol and lactitol are used to replace sucrose in applications that require very controlled crystallization for smoother textures, such as that desired in chocolates (Figure 6).

The polyols that are highly water-soluble also tend to be very hygroscopic, which is the ability to readily absorb water. Using polyols that are very low in hygroscopicity, such as erythritol, isomalt and mannitol, results in products that do not absorb moisture, thus reducing the potential for "cold flow" and stickiness. Crystallized sweeteners do not reduce water activity resulting in lower shelf stability.

Eating Sensation and Color Development

All polyols exhibit negative heats of solution, resulting in a cooling sensation when dissolved in the mouth, a key element of the third sensory goal. The intensity of this cooling effect depends on the magnitude of the heat of dissolution. Maltitol and isomalt show no cooling effect, while xylitol imparts a strong cooling sensation (Figure 7). Polyols also exhibit good heat and acid stability and do not undergo browning reactions, which can be advantageous in those applications where color development is not desired.

Other Functional Bulking Agents

Polysaccharides, such as maltodextrins and soluble fibers, can serve as strong, functional sugar substitutes. In confections, maltodextrins act as bulking agents and may also be used to provide foam stabilization, control sucrose crystallization, form a barrier layer before panning, act as a glaze on panned goods and, lastly, serve as a binder in tableted confections.

Soluble fibers allow for closer one-to-one replacement of sugar in most applications. The combination of high water solubility and high solution viscosity (at Brix ≥70%) of soluble fibers facilitates the processing of sugarfree and reduced-sugar candies. Soluble fibers develop slightly higher viscosities, although they are typically similar to sucrose. Insoluble fibers develop significantly higher viscosities than sucrose and are not recommended for sugar replacement in confections (Figure 8).

Soluble fibers, including polydextrose, inulin, soluble corn fiber and wheat dextrins, are amorphous and do not crystallize at low temperatures or high concentrations. These qualities control polyol and sugar

Polysaccharides, such as maltodextrins and soluble fibers can serve as strong, functional sugar substitutes.

Solubility Comparison

Compound	Solubility (25°C)
Dextrose	51
Fructose	80
Maltose	46
Sucrose	67
Maltodextrin	Varies with DE
Sorbitol	73
Maltitol	64

Figure 5 *Tate & Lyle 2010*

Crystallization Comparison of Multiple Bulking Agents

Function	Sweetener
Non-crystallizable; highly soluble	Corn syrup Corn syrup solids Soluble fiber(s) Maltodextrin Maltitol syrups Sorbitol syrups Polyglycitols
Difficult to crystallize	Fructose Allulose
Readily crystallizable; reduced solubility	Sucrose Dextrose Other polyols (sorbitol, erythritol, maltitol, etc.)

Figure 6 *Tate & Lyle 2010*

Cooling Effect of Several Sugar Alcohols

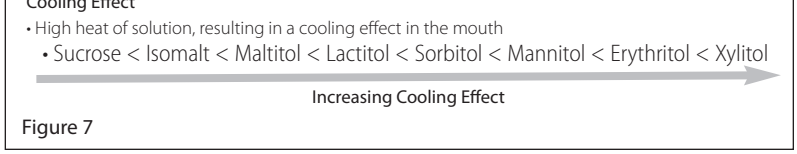


Figure 7

Petitions to the FDA are under review to determine the best way to label a functional, non-digested sugar under current definitions.

crystallization. Key to achieving functional goals, the control of crystallization ultimately changes the structure and texture of the finished product.

Since soluble fibers resemble the hygroscopicity of sugars, they readily bind with water, increasing water activity and making water more mobile within the matrix. With increasing temperatures and increasing moisture (high humidity), the effect on the glass transition temperature decreases which can result in shape deformation, stickiness and pooling. Increasing temperatures and decreasing moisture (low humidity) causes an increase in glass transition temperature, leading to brittle and tough textures.

Utilizing the functionalities of bulking sweeteners or polyols in combination with soluble fibers results in ideal textures and overall product stability, important in achieving the fourth goal. Such combinations enable innovative new products and more control of ingredient interactions in existing products. Once texture and stability are addressed with the bulking agents, controlling sweetness can be addressed.

NEXT GENERATION INGREDIENTS

Sugar reduction is becoming easier with the invention of new ingredients such as the next generations of stevia with improved flavor, sodium-based flavor modulators and new, natural masking agents. One promising advance is the use of non-digested sugars. Non-digested sugars, like allulose, contribute to the functionality required in confections while maintaining the "healthy" halo with a very low calorie count and no effect on blood glucose or insulin levels. However, allulose is still listed on the ingredient declaration as an added sugar. Petitions to the FDA are under review to determine the best way to label a functional, non-digested sugar under current definitions.

Viscosity Comparison of Various Bulking Agents

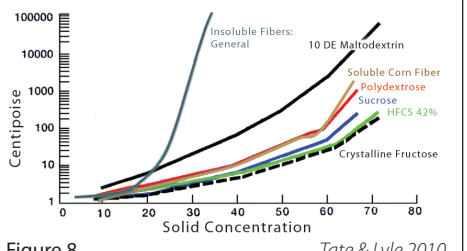


Figure 8 *Tate & Lyle 2010*

CONSUMER EXPERIENCE

In the confection world, reducing sugar is difficult from a technical perspective and can also affect the consumer in ways beyond the point of consumption. Gastrointestinal intolerances are related to the consumption of many of the polyols and soluble fibers needed to reduce sugar and maintain overall functionality and thus special care should be placed on formulations of those products where larger portions are consumed.

The significantly higher costs to source and manufacture healthier options in confections without sacrificing product quality are also restrictive. Partial sugar reductions or smaller serving sizes may be an easier option in reaching the targeted reductions while maintaining the eating experience of the consumer.

In confections, sugar gives structure to hard candies and texture to grained confections. Whenever sugar, or any significant ingredient, is removed from a formula, something has to be added back to maintain the proportions of the other ingredients and to sustain the desired product quality and stability.

CONCLUSION

No matter how you "cut the sugar" the confectionery segment is still expected to grow in 2019 and to continue that growth through 2021. Again, no matter the demand for reduced sugar options, this forecast is a clear indicator that most consumers still value the indulgence of the sugar-based candies they grew up enjoying and sharing. □

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